Facet Analysis and Semantic Frames†

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Abstract: Various fields, each with its own theories, techniques, and tools, are concerned with identifying and representing the conceptual structure of specific knowledge domains. This paper compares facet analysis, an analytic technique coming out of knowledge organization (especially as undertaken by members of the Classification Research Group (CRG)), with semantic frame analysis, an analytic technique coming out of lexical semantics (especially as undertaken by the developers of FrameNet). The investigation addresses three questions: 1) how do CRG-style facet analysis and semantic frame analysis characterize the conceptual structures that they identify?; 2) how similar are the techniques they use?; and, 3) how similar are the conceptual structures they produce? Facet analysis is concerned with the logical categories underlying the terminology of an entire field, while semantic frame analysis is concerned with the participant-and-prop structure manifest in sentences about a type of situation or event. When their scope of application is similar, as, for example, in the areas of the performing arts or education, the resulting facets and semantic frame elements often bear striking resemblance, without being the same; facets are more often expressed as semantic types, while frame elements are more often expressed as roles.

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1.0 Introduction

By their nature, some (sub)disciplines are deeply concerned with the conceptual structure of specific domains of knowledge. Included among them are computer science (data modelling), library and information science (knowledge organization), and linguistics (lexical semantics). Each of these fields has theories, techniques, and tools for identifying and representing the structure of knowledge domains. Despite their different approaches, it would be unsettling if the structures these techniques produce for a given knowledge domain had no overlap. The purpose of this paper is to compare facet analysis, an analytic technique coming out of knowledge organization, with semantic frame analysis, an analytic technique coming out of lexical semantics. How do they characterize the conceptual structures that they identify? How similar are the techniques they use? How similar are the conceptual structures they produce?

2.0 Characterization of conceptual structures

The conceptual structures of interest to us are those undergirding specific domains of knowledge, whether broad (e.g., the life sciences) or narrow (e.g., holography). The scope of these conceptual structures reflects the disciplines out of which they come; facets reflect the organization of the bibliographic resources of the knowledge domain, while semantic frames reflect the organization of language used to communicate about the knowledge domain.

2.1 Facets and conceptual structures

Proponents of facet analysis sometimes explain it by contrasting facet analysis with a traditional approach to classification in which, by repeated applications of various characteristics of division, subjects within the universe of knowledge are enumerated and represented as an inverted tree. Facet analysis differs from this approach in fundamental ways. Rather than organize the (potentially very

large) set of subjects that combine the values of those characteristics of division, facet analysis organizes the values of the characteristics of division and then provides for their combination. Top-level characteristics of division used to derive concepts from a parent class are the facets of the class, while the values of those characteristics of division are foci.

Thus, in facet analysis, the fundamental conceptual structure for a domain is a set of facets. According to Vickery (1960, 12), facets are, as we have just seen, the characteristics of division by which the vocabulary of a field is derived from the overall field. Alternatively, facets can be characterized as the "logical categories" underlying the terminology or general relations between the terms. Svenonius (2000, 143) characterizes facets as "semantically cohesive categories."

For Ranganathan, the top-level characteristics of division are manifestations of five fundamental categories: personality, matter, energy, space and time. Personality, matter and energy may recur within a field of study through rounds and levels. The Classification Research Group (CRG), which has championed the use of facet analysis in the development of bibliographic classifications, has suggested that Ranganathan's personality, matter and energy could be better understood as entities, properties and activities (Langridge 1976, 16).

While members of the CRG ([1955] 1997, 7) recognized that Ranganathan's fundamental categories could be "helpful in making a first approach to … subjects," they did not find it (Foskett 1959, 869) "necessary to keep within the limits of these fundamental categories in order to use the technique of facet analysis." The CRG (Foskett 1974, 120) "remained content with a pragmatic approach, identifying facets by reference to the literature itself of any subject to be classified." CRG-style facets thus are subject-specific, and it is this perspective on facets to which we will compare frame semantic analysis.

2.2 Semantic frames and conceptual structures

According to Ruppenhofer et al. (2016, 7-8), a semantic frame is "a script-like conceptual structure that describes a particular type of situation, object, or event along with its participants and props." The participants and props are generalized as frame elements. In frame semantics, the situation/object/event being described is characterized as a gestalt, in which the understanding of any element of the frame is dependent on understanding all other elements of the frame.

For example, fine, payer, reason, and speaker are frame elements within a fining frame (all semantic frame examples are taken from FrameNet, an online lexical database of semantic frames, available at https://framenet2.icsi.berkeley.edu). Because of the gestalt nature of the frame, its meaning can be revealed by stating the interrelationship of the frame elements: "The payer is (legally) forced to pay a fine by an official speaker as a punishment for some action (the reason). The speaker represents an entity which receives the payment." Elaborated descriptions of any specific frame element typically relate it to at least one other frame element; for example, "The speaker is the person who imposes the fine upon the payer."

Sentences use words that evoke specific semantic frames; words and phrases in the sentence then correspond to specific frame elements of the evoked frames. For instance, in the sentence, "They were fined approximately $3.1 billion dollars for their knowing, malicious injury to consumers," the verb "fined" evokes the fining semantic frame; "they" corresponds to the payer; "approximately $3.1 billion dollars" corresponds to the fine; and "for their knowing, malicious injury to consumers" corresponds to the reason. The identity of the speaker is not given in the sentence; indeed, the speaker is not explicitly mentioned in the sentence. But the speaker is nonetheless present, if only implicitly: we can't have fining without someone's imposing the fine.

3.0 Techniques for identifying conceptual structures

Examining similarities and differences in how facets and frame elements are identified will help us better understand why the resulting conceptual structures often have similarities, but are seldom identical. Facet analysis and frame semantic analysis both start with written text as input. As we will see, the details of how they examine that input differ; sorting semantic components of words (for example, those in titles) into groups of shared semantic type contrasts with investigating the semantic argument structure of sentences using specific words. The techniques used account for only part of the differences in the final results.

3.1 Identifying facets

Vickery (1960, 20) notes that while facet analysis is, in essence, the conceptual analysis of a subject domain, advantages accrue from basing the analysis on the literature of the subject. The main advantage is that the facets identified on the basis of a field's literature will be the facets needed to organize the literature, the typical goal of facet analysis. Alternatively, of the many characteristics of division that might be used within the subject domain, only those that are significant in its literature will be pulled out when the literature is used in the facet analysis process.

But what exactly do we mean by the literature of the field? Vickery (1975, 17) makes clear that facet analysis

begins by processing terms taken from a variety of sources, for example, textbooks, glossaries, lists of subject headings, and existing classifications and subject indexes. Langridge (1976, 100) suggests instead drawing terms from article titles. These subject terms may be conceptually complex. Soergel (1985, 251-261) describes how to perform semantic factoring to identify the semantic components underlying them.

The (semantic components of the) terms are then sorted into groups, based on the characteristics of division used to differentiate each term. Since this process is performed somewhat intuitively, lumping and splitting of groups may take place as additional terms are analysed. The highest-level groups at the end of this sorting into groups are the facets. Vickery (1975, 10) illustrates the result of such a process with six chemistry terms: "alcohol" is a kind of chemical substance; "liquid" is a state of that substance; "volatility" is a property, while "combustion" is a reaction; "analysis" is an operation; "burette" is a device for carrying out an operation.

3.2 Identifying frame elements

Using as evidence the British National Corpus (available at http://www.natcorp.ox.ac.uk), U.S. newswire texts from the Linguistic Data Consortium (available at http://www.ldc.upenn.edu), and the American National Corpus (available at http://anc.org), the Berkeley FrameNet project (available at https://framenet.icsi.berkeley.edu; Baker et al. 1998; Fillmore et al. 2003; Ruppenhofer et al. 2016) begins the frame element identification process by identifying word senses with semantic overlap, that is, senses of a word that can be used to talk about the same situation or answer the same question. (Although this analysis is approached in as principled a fashion as possible, the grouping of word senses is subject to the same iterative process of lumping and splitting as is the grouping of terms in facet analysis.) Sentences containing those word senses are then annotated to document how the syntactic elements (words and phrases) in the sentence combine to express a set of semantic relationships. More specifically, this examination of each sentence's predicate-argument structure identifies the semantic roles played by noun phrases in syntactic relationships with the verbs that are said to evoke the frame (Ruppenhofer et al. 2016, 7, 9). Recurring semantic roles are identified as frame elements of the frame; of these, some are designated as core frame elements, others as non-core frame elements.

For example, specific senses of the verbs deceive, fool, mislead, and trick can be used to communicate about the same situation or answer the same questions. The following sentences, taken from FrameNet's corpora, illustrate:

1. The government deceived the public last year about the existence of evidence in several corruption trials.
2. I can't believe they fooled me with that old trick.
3. You deceived me about the location of the diamonds.

This situation is known in FrameNet as Intentional_deception (compare with https://framenet2.icsi.berkeley.edu/fnReports/data/frameIndex.xml?frame=Intentional_deception), where this description is given: "A Deceiver performs some action so that the Victim ends up with an incorrect understanding about some Topic. The Means may be via communication, perceptual obscuration, or merely performing an action that the Victim will draw incorrect conclusions from." The three core frame elements in this frame are the deceiver (e.g., "the government" in 1, "they" in 2, "you" in 3), the victim ("the public" in 1, "me" in 2 and 3), and the topic ("about the existence of evidence in several corruption trials" in 1 and "about the location of the diamonds" in 3). These frame elements are said to be core, because every instance of intentional deception involves a sentient deceiver, a victim of the deception, and some premise or topic that the deceiver intends that the victim will misapprehend. A sentence that evokes a semantic frame may fail to express the identity of a core element (for example, the topic is not expressed in 2), but every core element is understood to be involved in the state or event that the sentence communicates about. For example, with 2, it is understood that they have fooled me about something; that something is the topic.

The predicates in the sentences being annotated may also include additional arguments; these often correspond to non-core frame elements. For example, sentence 1 has an argument ("last year") that expresses time, which is when the deception took place. Sentence 2 has an argument ("with that old trick") that expresses means and indicates what the deceiver has done that results in the victim's being deceived. Place is yet another non-core frame element.

As can be seen here, many non-core frame elements are general and function as core frame elements only in very general frames; such frame elements function similarly to common facets. Means, for example, is considered a core element in FrameNet's Means frame, a frame in which an agent uses a means to achieve a purpose, all of which are core frame elements in that context. A variety of relationship types may exist between frames, the most important of which are the inheritance relationship, the using relationship, the subframe relationship, and the perspective relationship. Relationships between frames are largely dependent on and/or interact with relationships among the frame elements. For example, the deceiver in the Intentional_deception frame corresponds to the agent of the Means frame when means occurs as a

non-core frame element in the Intentional_deception frame, while the purpose of the means will be to mislead the victim of the Intentional_deception frame with respect to the topic.

4.0 Conceptual structures produced

How similar are the results of facet analysis and semantic frame analysis when applied to a common domain of knowledge? We will examine this question by comparing the facets identified in four faceted classifications, namely in the subject areas of the performing arts, education, occupational safety and health, and manufacture, with the closest corresponding semantic frames.

4.1 The performing arts

Antony Crogan's (1968) faceted classification of the performing arts addresses the theatrical arts, specifically, drama, opera, ballet, film, television, and radio, and recognizes the following core facets:

- Form of art
- Subject
- Style
- Space and time
- People
  - Creators
  - Performers
  - Technicians
  - Audience
- Production
- Processes and techniques

The corresponding Performing_Arts frame in FrameNet carries the following definition: "The Performers, together with behind the scenes Personnel, execute a Performance according to a Script and/or Score. The purpose of the Performance is to create an experience for an Audience, who then judge its merits. Performances may be in many different Mediums and be of various Types." Core frame elements are characterized in FrameNet as given below:

- Audience: The audience experiences the performance.
- Medium: Medium is the physical entity or channel used by the performer to transmit the performance to the audience.
- Performance: The experience generated by the performers and perceived by the audience.
- Performer: The performer provides an experience for the audience.
- Personnel: The personnel, including writers, producers, stage hands, key grips, etc., contribute to the performance without actually being directly perceived by the audience.
- Score: The score may be performed in the performance, either in isolation or accompanying actions and speech.
- Script: The (usually written) directions which instruct the performers on what actions to perform, when, and how. It has many different names depending on the type of performance including script, screenplay, libretto, book, and choreography.
- Type: The type of performance, including dance, theatre, film, etc.

Table 1 shows the facets and frame elements that correspond to one another.

Facet	Frame element
Form of art	Type
People: Creators	Personnel
People: Performers	Performer
People: Technicians	Personnel
People: Audience	Audience

Table 1. Facets vs. frame elements: performing arts.

Moreover, there are facets (production, and processes and techniques) for activities that result in a performance, an unmatched frame element with which medium, score, and script are closely related. But there are also facets that are not represented among the frame elements (subject; style; and space and time). Although Crogan designates subject and space and time as core facets, one could argue their marginality. The style facet, however, is inexplicably missing from the Performing_arts semantic frame.

4.2 Education

The *London Education Classification* (Foskett and Foskett 1974), in use at the University College London (UCL) Institute of Education, identifies these core facets for the field of education (some facets are combined in the classification for practical purposes; they have been separated here for purposes of comparison):

- Educands
- Schools
- Curriculum
- Teaching method
- Students' work
- Teaching profession
- Educational psychology and measurement

– School, college, and university management
– School, college, and university officers
– School buildings
– Equipment

Education_teaching, a semantic frame in FrameNet of similar, but not identical, scope, has the following definition: "A Student comes to learn either about a Subject; a Skill; a Precept; or a Fact as a result of instruction by a Teacher." Core frame elements are characterized in FrameNet as given below:

– Course: A program of lectures or other matter dealing with a subject.
– Fact: A piece of information that the student is informed of by the teacher.
– Institution: An educational establishment, such as a school or college.
– Material: Educational material, such as books, tapes, or videos, used by a teacher or a student to acquire skills or knowledge.
– Precept: A guideline for correct behaviour.
– Qualification: A formal qualification, such as an academic degree or a certificate, for which a student is aiming.
– Role: A role, typically professional or vocational, that the student is meant to be able to fill as a result of their training.
– Skill: An action which the student is able to perform as a result of instruction.
– Student: One who is instructed by a teacher in skills or knowledge.
– Subject: The area of knowledge or skill which is taught by a teacher or to a student.
– Teacher: One who instructs a student in some area of knowledge or skill.

Table 2 shows the facets and frame elements that correspond to one another. Educands and students appear to be equivalent, as do schools and institution. The curriculum facet includes traditional subjects, but also such issues as curriculum design and curriculum reform, which are absent from the subject frame elements. In the Education_teaching frame, subject is something that a student can learn, as are facts, precepts, and skills. Although the curriculum and subject concepts overlap, they have different emphases as facet and as frame element. The school, college and university officers facet, which include, inter alia, chancellors, deans, librarians, and registrars, is broader than the teachers frame element.

Additionally, there are facets that are not represented among the frame elements (teaching method; students' work; teaching profession; educational psychology and measurement; school, college, and university management; school buildings; and equipment) and frame elements that are not represented among the facets (course, material, qualification, and role). The differences here probably do not represent differences between facet analysis and semantic frame analysis so much as they represent differences in perspective: the London Education Classification puts greater emphasis on the provision of education, on what educators do, while the Education_teaching frame puts greater emphasis on the reception of education, on what education prepares the student for.

Facet	**Frame element**
Educands	Student
Schools	Institution
Curriculum	Subject/Fact/Precept/Skill
School, college and university officers	Teacher

Table 2. Facets vs. frame elements: education.

4.3 Occupational safety and health

Foskett (1959, 869-870) developed a faceted classification for occupational safety and health used in the library of the International Labour Organization (International Occupational Safety and Health Information Centre 1966), in which the following core facets occur:

– Special classes of workers; industries: where hazards exist
– Sources of hazards: the things causing danger
– Accidents and diseases: the results of the hazards
– Prevention: the means by which the worker is protected.

FrameNet does not have any frames corresponding directly to occupational safety and health, but it does have frames for risk and protection that cover some of the same ground. Given here are FrameNet's descriptions and core frame elements:

– Being_at_risk: An asset is in a state where it is exposed to or otherwise liable to be affected by a Harmful_event, which may be metonymically evoked by reference to a Dangerous_ entity.
  – Asset: Something judged to be desirable or valuable which might be lost or damaged.
  – Dangerous_entity: A concrete or abstract entity which may come to cause the loss of, or damage to the asset.
  – Harmful_event: An action that may occur or a state which may hold which could result in the loss of or damage to the asset.

- Run_risk: A protagonist is exposed to a potentially dangerous situation that may end in a Bad_outcome for him- or herself.
  - Action: The action that creates the risk.
  - Asset: Something desirable possessed by or directly associated with the protagonist which might be lost or damaged.
  - Bad_outcome: A situation that the protagonist would like to avoid.
  - Protagonist: The person who is at risk of some Bad_outcome
- Protecting: Some protection prevents a danger from harming an asset.
  - Asset: Something desirable possessed by or directly associated with the protection which might be lost or damaged.
  - Danger: A situation that could damage the asset.
  - Protection: The person, entity, or action that prevents harm to an asset.

Table 3 shows the facets and frame elements that correspond to one another, although with this comparison, correspondences are only partial. FrameNet's risk-related and protection frames are completely open with respect to the context in which they are applied; this contrasts with the focus of the faceted classification on occupational safety and health. Not surprisingly, the industries facet, as a place where hazards exist, is absent from the relevant semantic frames. And the accidents-and-diseases facet in the occupational safety and health classification are only two of the possible bad outcomes accommodated in the Run_risk semantic frame.

Facet	**Frame element**
Special classes of workers; industries: where hazards exist	Asset; Protagonist
Sources of hazards: the things causing danger	Dangerous entity / Harmful event; Danger
Accidents and diseases: the results of the hazards	Bad_outcome
Prevention: the means by which the worker is protected	Protection

Table 3. Facets vs. frame elements: occupational safety and health.

4.4 Manufacture

Vickery (1960) gives facets for the manufacture of two different products, pharmaceutical manufacture (9-10) and container manufacture (27); the scope of this latter classification is container manufacture and packaging, but for purposes of comparison, we restrict our investigation to only the container manufacture aspects of that classification:

- Pharmaceutical manufacture
  - Products
  - Starting materials
  - Substances to be extracted
  - Reactions
  - Agents
  - Physico-chemical operations
  - Agents
  - Properties of agents
  - Scale of operation
- Container manufacture
  - Products
  - Parts, components
  - Materials
  - Operation of manufacture
  - Machinery for manufacture
  - Machinery for processing.

By looking at what the two facet analyses have in common, we determine the core facets of manufacturing, which are:

- Products
- Materials
- Operations.

The manufacturing frame in FrameNet carries the following description: "A Producer produces a Product from a Resource for commercial purposes." Core frame elements are characterized below, as given in FrameNet (as of August 2017, the FrameNet website lists Factory ["the particular plant where the Product is manufactured"] as a core frame element, but lists resource as a non-core frame element; the frame description suggests that the list given here is correct):

- Producer: The person or company that produces the product.
- Product: The product is produced by the producer.
- Resource: Resource is the material that the product is made from.

Table 4 shows the facets and frame elements that correspond to one another. The operations facet of faceted classification is missing from the Manufacturing frame, while the producer frame element of the Manufacturing frame is absent from the faceted classification.

Facet	**Frame element**
Products	Product
Materials	Resource

Table 4. Facets vs. frame elements: manufacture.

But the focus of the faceted classifications is not manufacture per se; rather, it is pharmaceuticals manufacture and container manufacture. FrameNet has a Medical_intervention frame, where the intervention frame element can be a drug or a procedure; other core frame elements include Medical_condition, Medical_professional, and result. FrameNet also has a containers frame, which is defined in terms of containers and contents. The frame elements of these two additional frames have little to do with the other facets needed for pharmaceuticals manufacture and container manufacture.

5.0 Discussion

The degree of correspondence we have found between the facets of subject-specific faceted classifications and the frame elements of related semantic frames reflects both similarities and differences between facet analysis and frame semantic analysis. Indeed, the number of exact or close matches we have found raise the possibility that facets and frame elements are essentially the same thing, although semantic types (e.g., people, processes, techniques, officers, accidents, diseases) are found more often among facets, while semantic roles (e.g., audience, performer, teacher, protection, producer) are found more often among frame elements.

If this is so, where do the differences we have found come from? One answer is that they come from the same source as the similarities, that is, from the textual input being analysed. We surmise that if facet analysis and frame semantic analysis were applied to the same textual input, their results would be yet more similar, given that both consider what semantic role is played by textual elements (terms in the case of facet analysis, syntactic units in the case of frame semantic analysis) in that input.

In what sense is the textual input different? Simply this, that faceted classifications tend to investigate scholarly or technical literature, while frame semantics tend to investigate balanced corpora, in which only a limited portion of the texts is scholarly or technical in nature. As a result, faceted classifications are likely to reflect better the interests of business and academia, the producers of products and research, while frame semantics is likely to reflect better the interests of consumers and end users.

The differences also reflect the different uses to which faceted classifications and semantic frames are put. Faceted classifications are used to organize literature. Semantic frames are fundamentally a secondary tool, used to inform other tools, especially natural language processing tools. While faceted classifications specialize by subject, semantic frames specialize by linguistic phenomena, specifically the interaction of syntactic and semantic phenomena.

6.0 Conclusion

The reader may respond, "This is all very interesting, but so what? Is there any way in which the work of faceted classification can inform the work of frame semantics, or vice versa?" On the one hand, the differences we have just seen between faceted classifications and frame semantics lead us to conclude that neither effort can render the other effort unnecessary. On the other hand, just as the CRG acknowledged that Ranganathan's PMEST formula could be used as a starting point in devising a faceted classification, so too might the frame elements in relevant frames, if such can be identified in FrameNet.

Preliminary work has been done on the automatic identification of facets (Green 2014), based on measuring density of subject-related title words in WordNet (available at https://wordnet.princeton.edu). Work of this nature might likewise provide foundational data for identifying and characterizing frame elements, given that the linguistic scope of WordNet is similar to that of the balanced corpora used in FrameNet.

In the end, however, the different uses to which faceted classifications and semantic frames are put mean that the assistance each technique can provide the other is probably limited.

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